# MOLECULES AND MAN

*By*

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# Molecules and Man

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AN industry which produces over a billion dollars' worth of finished products is important; an industry which makes a billion dollars' worth of invisible particles is interesting; an industry which insures our future is valuable; an industry which defends our homes is essential. It is the Chemical Industry which does all of these things and it, therefore, is of primary interest to all citizens because of its direct influence on national prosperity. It is as essential to modern civilization as agriculture is to any civilization.

Human accomplishment, insofar as material products are concerned, is entirely dependent on man's intellectual development and on the materials at his disposal. The great advance in the arts which has taken place in recent times is a direct out-



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come of man's success in making new substances, substances which do not exist as such in nature. This advance during the past century has been greater than during all previous history and during all that time which passed before the beginning of recorded years.

Some may object that the primary cause of all recent progress in the mechanical arts is to be found in Watt's invention of the steam engine, which has grown to mean all the multitudinous steam-driven devices of every description whose motions are the heart beats of industry. But in truth Watt's discovery was the outcome of one made long before, when man found that from red rust he could obtain metallic iron.

It is no coincidence that the unparalleled development in all human enterprise which the past half century has seen has coincided with the introduction of many new materials, the discovery of new methods of obtaining in quantity many substances which were formerly only rarities, and the large-scale production of substances by much cheaper means.

To the useful metals of the ancients none was added until aluminium was extracted from clay by the chemists of to-day. It is easy to extract gold and silver which are found as metallic particles in the earth's crust; harder to obtain iron, zinc, copper and tin, which occur as substances in which the metal is as much hidden as the charcoal in sugar. But it is most difficult to obtain aluminium, which can be extracted only by the aid of the electric current; and that is why it remained unknown for so many hundreds of years. Likewise the metals chromium, vanadium, tungsten, and molybdenum have become available for the benefit of man, who could have no automobile and no mazda light without them.

Even more astonishing has been the progress made in building substances nearly related to those which go to form the animal and plant body—organic substances, the compounds of carbon. In the case of metals, the chemist can only set them free; so far he has not found it possible to make metals which do not occur in some form in nature. But in the group of carbon compounds he produces substances as the need for them arises.

Thus the organic chemical industry today produces drugs to allay fever, to dispel pain, to calm the nerves and to stimulate the sluggish heart; dyes for wool, for silk and cotton, black and of every hue with properties to meet the requirements of the user, dyes of evanescent beauty of shade or of such ruggedness as to resist all harsh treatment; fibers of the glossy beauty of silk or of the coarseness of horse-hair; explosives; cosmetics; perfumes; disinfectants and foods.

In every walk of life we use these products of the organic chemist's skill. Indeed, so universally do we use or enjoy these that we lose sight of the fact that they were all unknown in the days of our great grandfathers and that our comfort is more than was theirs because of just these things.

Yet think what surgery without anesthetics means; that is, without ether, chloroform, nitrous oxide, and then consider that all these are substances made on the earth by chemists and do not exist in nature. Recall the great engineering feats of modern times—the Panama Canal, the great tunnels which have brought together nations

that for hundreds of years have been separated from each other by mountain barriers; then realize that these were made possible because man learned to make molecules out of the atoms which nature furnished, molecules endowed with the power of high explosives. And when next you see the tragicomedy of the screen moving to rapid fulfilment, take thought that this great factor in the lives of the people of all nations has come of the organic chemist's discovery of a film.

It is the province of the chemist to make new kinds of matter. To do so he must change each least unit of the substances he uses for his building. His units are molecules and the atoms of which molecules are composed. To him every substance in measurable quantity is an aggregate of innumerable molecules and of a still greater number of atoms. He knows that molecules can be built up, broken down, or the atoms in them rearranged; but that in each case the original substance disappears and another takes its place.

It is difficult to find a simile for this which will convey its meaning to those who

have no knowledge of chemistry. Perhaps the best is to say that molecules are like words, atoms like letters. If words are considered as concrete objects then it is possible to think of the dye indigo as a mass of units, each being the word "indigo."

In making this word (molecule) the chemist uses simpler words (molecules); some of only one letter, but still a word, like "I." He cannot use single letters that do not form words because nature only furnishes perfect molecules, though these are sometimes made of only one kind of matter. Given these simpler molecules, which may be represented as

I – gin – I – nod – dog – I

he puts them through processes which loosen the atoms from each other and cause them to become rearranged in a new order. Just as the words above can be regrouped to give

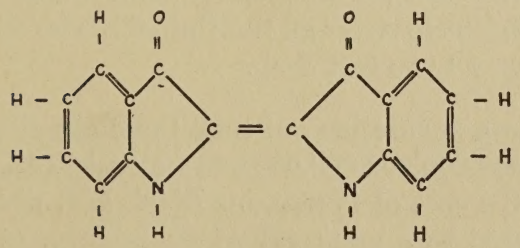
Indigo — Indigo.

The individual letters do not change in word building—neither do the atoms in

making molecules. Evidently the same arrangement of atoms (letters) in a molecule always gives the same molecule (word) with identical properties. This analogy is close enough to make clear that the chemist is engaged in a sort of game in which with certain groups of atoms he is trying to find out how many different kinds of molecules he can make.

He has gone as far as producing over 100,000, all made of carbon (C), oxygen (O), hydrogen (H) and nitrogen (N), which shows that his units can be rearranged in more ways than can letters to form words.

As a matter of fact, the chemist does use letters when indicating his molecules on paper; but his spelling is strange. "Indigo" becomes:

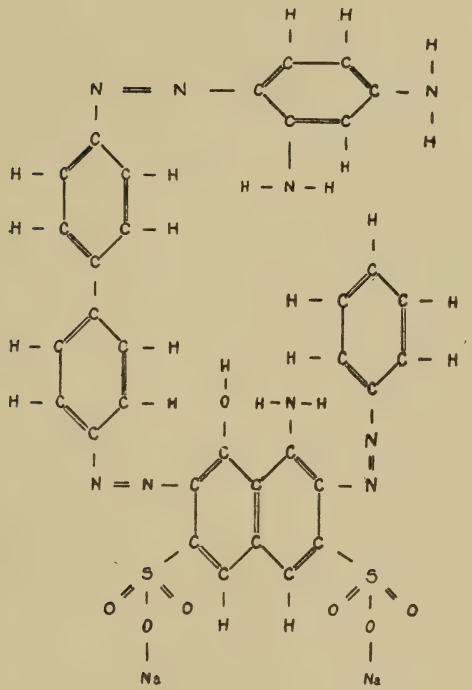


which is unpronounceable, but is a formula which has great advantages. "Indigo" brings to mind just a blue substance; written in the chemist's way, it means a certain number of atoms of carbon (C), of hydrogen (H), of oxygen (O) and of nitrogen (N), grouped in a definite order, telling him the relationship of indigo to other substances. In fact, once he learned that this was nature's way of spelling indigo he found that he could make it in a way nature never had used. This then is chemical industry: *the rearrangement of atoms to give more useful products than the molecules in which the atoms are supplied.*

But what makes the industry most astonishing is that its finished products, the molecules, are inconceivably small. A thimbleful of air contains 6,000,000,000,000,000,000 molecules. Were each of these to be converted into an orange, the fruit would be sufficient to cover all the United States with a layer 1,000 feet deep.

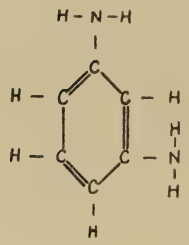
In a square inch of sock there are about 20,000,000,000,000,000,000 molecules of dye. In the case of Pontamine Black EX, which is used to a great extent for hosiery, each

molecule is composed of seventy-nine atoms in this order:

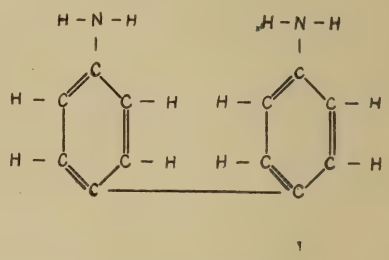


The building up of such a molecule requires a long series of processes which can be made clearer by using the chemist's method of drawing molecule pictures.

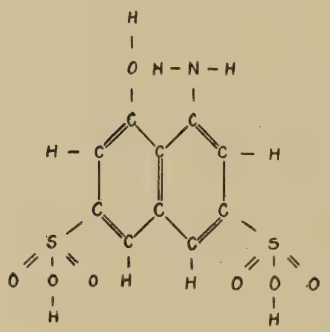
The molecules of intermediates from which it is made are these:



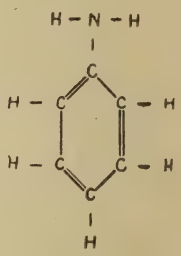
METAPHENYLENE DIAMINE



BENZIDIN

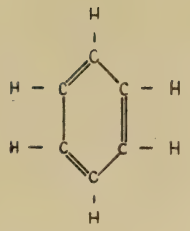


H. ACID

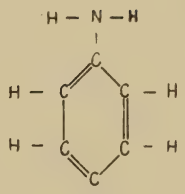


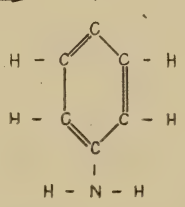
ANILIN

These intermediates are in turn made from the crudes benzene and naphthalene in this way:

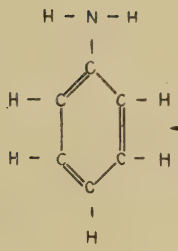


BENZENE

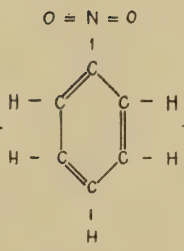




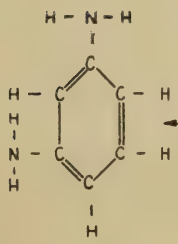
BENZIDINE



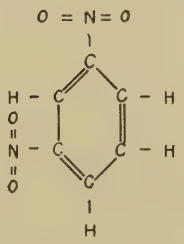
ANILIN



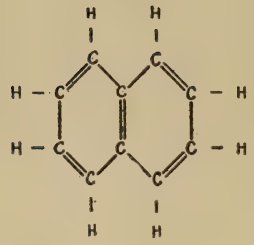
NITRO BENZENE



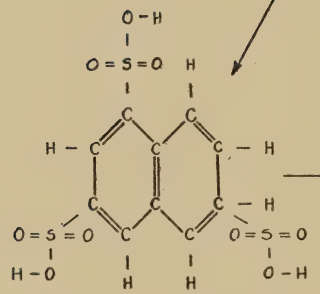
META PHENYLENE DIAMINE



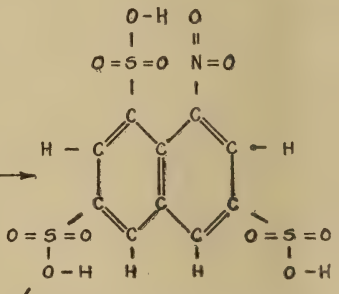
DINITRO BENZENE



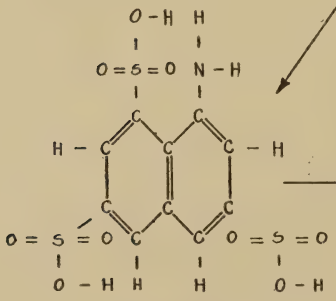
NAPHTHALENE



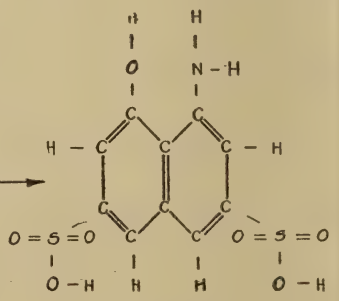
NAPHTHALENE TRI SULPHONIC ACID



NITRO NAPHTHALENE TRI SULPHONIC ACID



KOCH ACID



H. ACID

It should be understood that every succeeding formula represents a distinct manufacturing operation, involving other molecules, such as sulphuric acid, which are not shown. Each is repeated billions and billions of times in every batch of color. There is no other industry which can even approach the record of the dye business for unit output. What other industry can sell 40,000,000,000,000,000,000,000 pieces of one of its main products for a dollar? Every pound of Pontamine Black EX contains about 40,000,000,000,000,000,000,000 molecules, each composed of its seventy-nine atoms, every atom being in place and in the proper relation to the others, each molecule smaller than anything which the eye can see even with the highest-powered microscope. Tiny as these particles are, there are so many of them in the pound that if they were strung like beads on a string they would extend 130,000,000,000,000 miles, or roughly 710,000 times to the sun and back—a distance so vast that it would take light, moving at 196,000 miles per second, 21 years to traverse it.

Every molecule must be like every other to give a uniform dye and it does not mat-

ter whether the atoms are assembled here or abroad; the dye made up of the same molecules must be the same in every property. Germany did invent many dye molecules, but when these are made in America the resultant dye cannot differ from the German. To talk of a German molecule is absurd; to talk of the superior fastness of a German molecule when compared with that of the same molecule made in America is foolish and can only come of a lack of understanding. It is as unreasonable as to say that pure sugar made in Colorado can be less sweet than pure sugar made in Germany.

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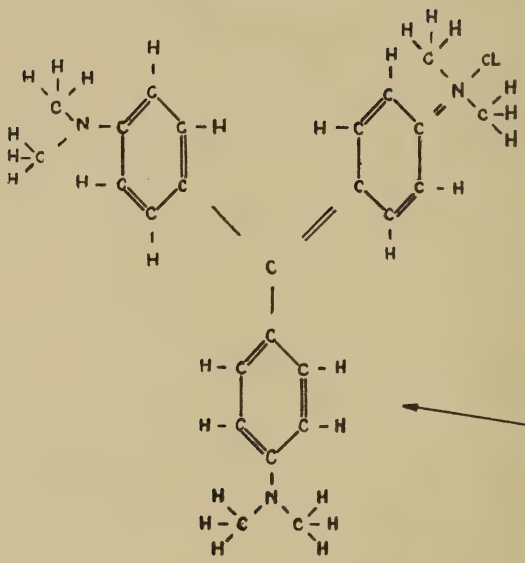
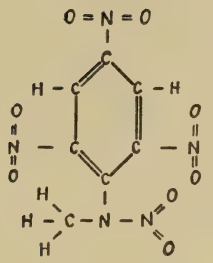
There is a necessity for a national organic chemical industry as a part of that organization which is needed as a preparation for war. This has been stated frequently, but not too often. When war comes, if it must, then the focus of national activity changes. Not the citizen, but the citizen soldier becomes paramount. He must be equipped; he must be made terrible for the offensive by all the means the nation has; he must be

made invulnerable in defense by all that he can be given. These two requirements mean a fundamental shift in the center of gravity of the nation's industry. Three essentials stand out—steel, explosives, food. Any one, without the other two, is useless. Two of these are chemical industries; the second is no less important than the first. Bayonets without bullets, shells without bursting charges—an absurdity! Explosives, all the materials of offensive warfare, are made by the chemist. There is no question about the steel industry; that is one grown strong in peace. But what of that other, the organic chemical industry, which is as essential? Its future among us is insecure! If the proposal were made to leave the country without a steel industry the nation would not tolerate the suggestion for a moment—but the industry of dyes and pharmaceuticals is just as essential.

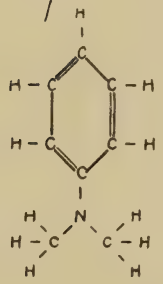
Anyone can see that the making of steel rails and boiler plate is closely related to making rifles, cannon and battleships. To see the relation of dye-making to T.N.T. and tetryl is not so easy. It is in this that our formulas will help us.



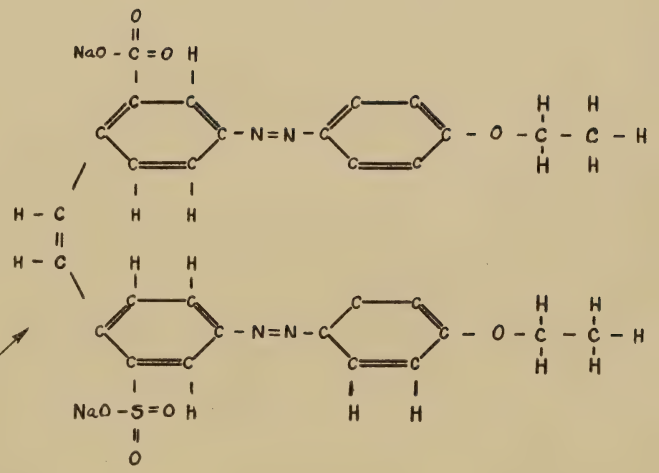

DU PONT CRYSTAL VIOLET



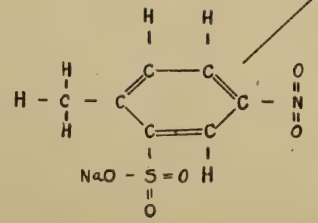
HIGH EXPLOSIVE
TETRYL



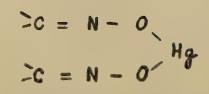
INTERMEDIATE
DIMETHYLANILIN



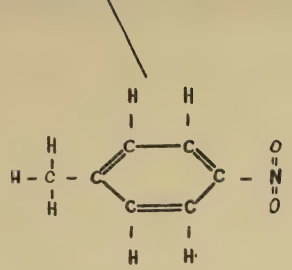
PONTAMINE YELLOW CH



INTERMEDIATE
PARA-NITRO TOLUENE SODIUM
SULPHONATE



DETONATOR
MERCURY
FULMINATE



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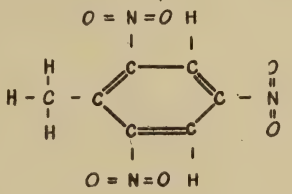
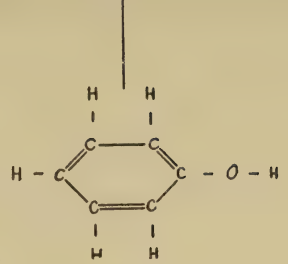
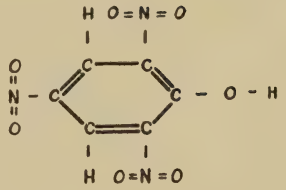
PARA-NITRO TOLUENE



HIGH EXPLOSIVE
T.N.T.



CARBOLIC ACID
PHENOL



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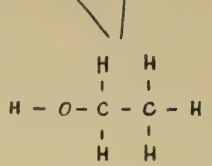
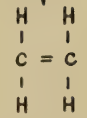
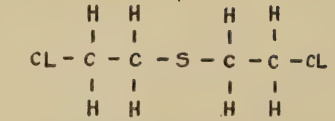
PICRIC ACID



ALCOHOL



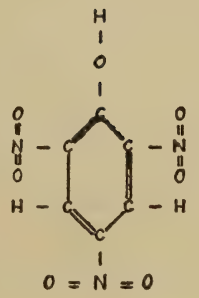
ETHYLENE



MUSTARD GAS

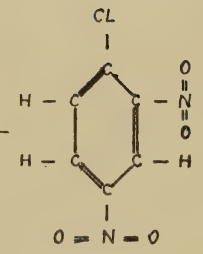
SULPHOGENE BLACK

FORMULA UNKNOWN



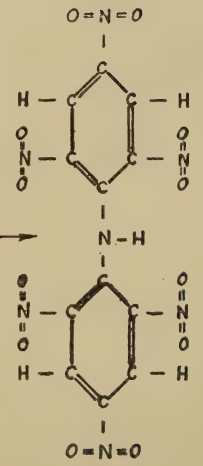
HIGH EXPLOSIVE

PICRIC ACID



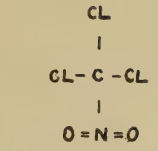
INTERMEDIATE

DINITRO CHLOROBENZENE

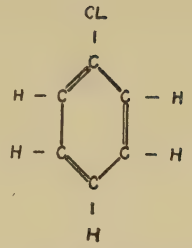


HIGH EXPLOSIVE

HEXA NITRO DIPHENYLAMINE




POISON GAS
CHLORPICRIN

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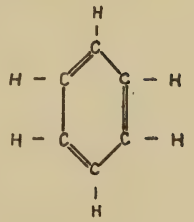
CHLOROBENZENE

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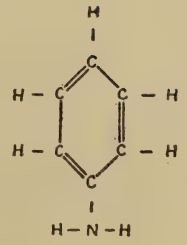
BENZENE



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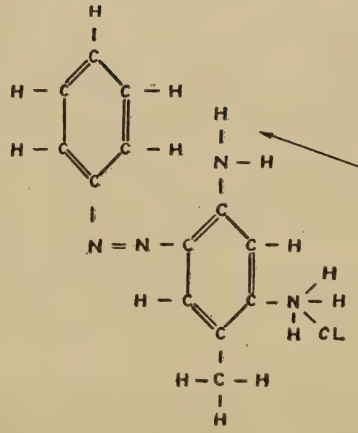
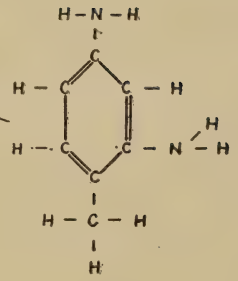
ANILIN



DU PONT CHRYSOIDINE R



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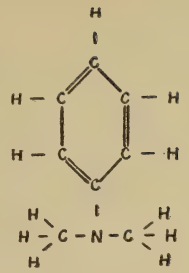

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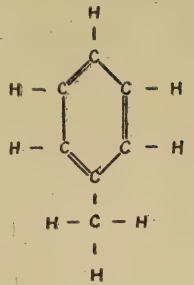
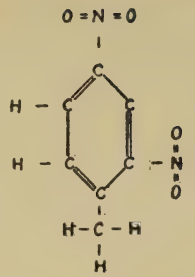


CRUDE
TOLUENE



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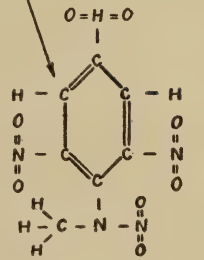
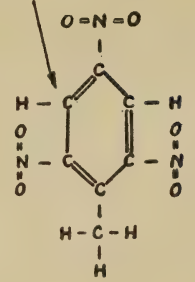
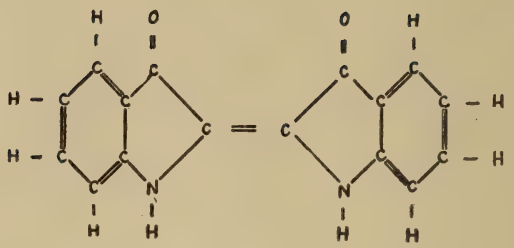
DINITRO TOLUENE



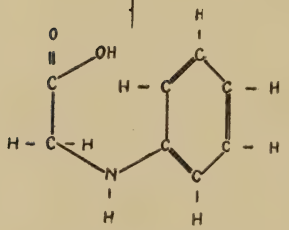
HIGH EXPLOSIVE
TETRYL



HIGH EXPLOSIVE
T.N.T.



DUPONT INDIGO



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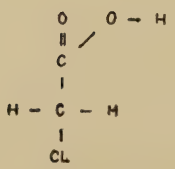
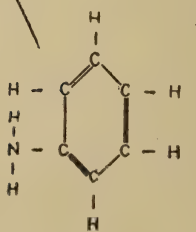


CHLORACETIC ACID



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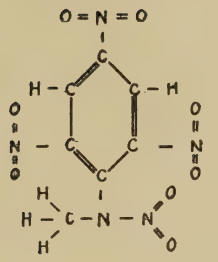
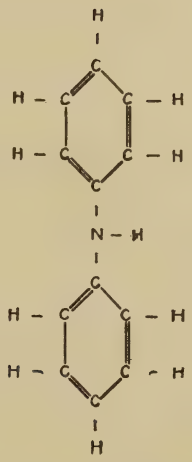
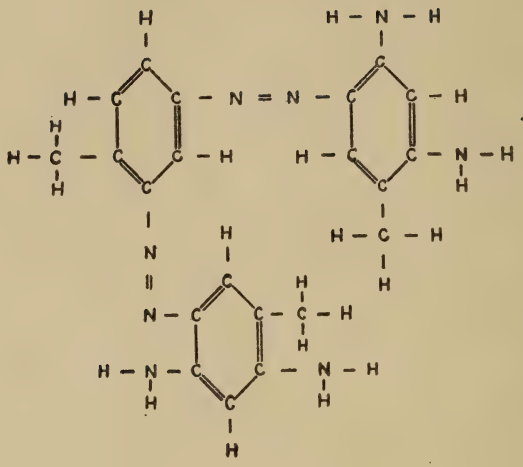
ANILIN



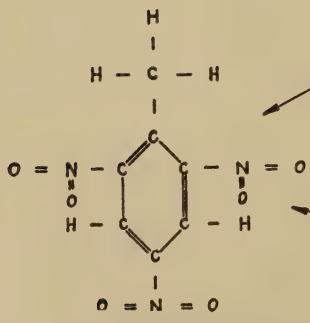
HIGH EXPLOSIVE
TETRYL



STABILIZER FOR SMOKELESS POWDER
DIPHENYLAMINE



DUPONT BASIC BROWN



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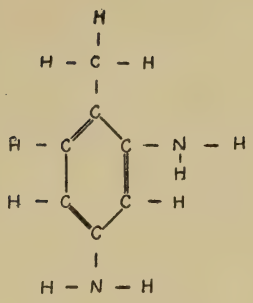

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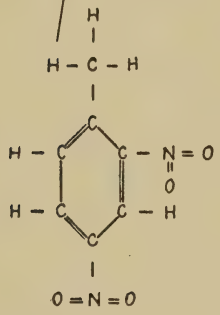
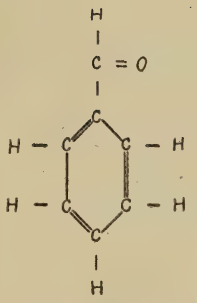
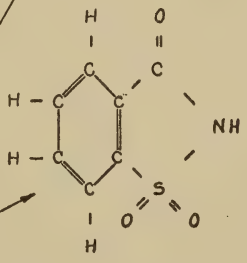


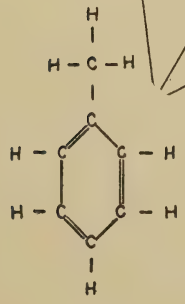
INTERMEDIATE
DINITROTOLUENE



SYNTHETIC OIL
OF
BITTER ALMONDS
BENZALDEHYDE



SACCHARINE



CRUDE
TOLUENE

It should be understood that the equipment and the processes used in making such dyes are very similar to those used in making munitions. It is, therefore, proper to say that a dye plant is a potential munitions factory and, as such, of the first importance to national defense. It takes years to perfect a dye plant; to have it ready means saving much precious time at the moment of national peril. Indeed, in the future it will come to having dye plants, or idle munitions factories, maintained at public expense, as the only alternatives by which security can be insured. A nation without a dye industry must have special plants in which to make explosives at a moment's notice. These will be a charge on the nation, but will be as essential as battleships, which are only really useful as a threat in time of peace. But idle munitions plants are needless if the nation has flourishing dye plants, kept always efficient.

More important even than plant and equipment are the trained men; those who can make dyes can make munitions, poison gases and everything else required. It does not take much study of the formulas given to make clear that manufacturing explosives

is a very highly specialized industry. The specialist is not made over night; he is the product of long training. From director to wage earner, the dyestuff plant is in the hands of just those specialists who are needed for making the materials used in warfare.

That we succeeded in the conflict just passed was largely due to the fact that we had a reserve of trained men in those who taught chemistry in our institutions of learning. They came forward and saved us from humiliation. We had those men and we had two years during which we learned how to make explosives before we needed to use them for ourselves. If the attack had been directly on us, much valuable time would of necessity have been lost while the college men were learning to handle materials on a large scale.

It is true that Germany, with all her chemists, went down to defeat; but think of her wonderful resistance with all the world against her. In that resistance the efforts of her chemists show. Indeed, it is probably true that she would have won the war had she trusted more to them.

A permanent dye industry will mean a great stimulus to organic chemistry in the universities; it will allow of keeping more academic men engaged in research, and it is this research and it alone which can keep us up-to-date enough to give us a chance in the adaptation of chemistry to war. Mustard gas was first made in the university laboratory in the course of purely scientific investigation. These discoveries come of active investigation, they are a part of a growth in which we must share to keep our independence.

Fortunately for mankind, peace is usual; war, unusual. During peace, however, national competition continues to exist in the shape of commercial rivalry, in the search for employment by wage earners. To meet this condition it is necessary for a nation to be efficient, to operate without waste, and to avoid placing itself in a position allowing of its being exploited. We have reached a very high degree of efficiency in manufacturing, but we have not yet learned all that we should about utilizing by-products. For years we burned all the coal tar we made; we let the by-products of coke-making pass without utilizing them—burned them to be

rid of them. The waste ran into very high figures.

We still burn too much of this, though the condition in the coking industry is much better than it is in that of lumber, which uses only 30% of its crude material and wastes the rest. A dye industry will mean saving one great waste; it may be objected that we do not need to destroy the coal tar by-products—that we can always export them to countries that are better fitted than we are to make dyes. That argument is not sound even in a selfish way, because it means that this nation should adopt a policy of living at the mercy of others. Before the war that is exactly what we did; we found out our mistake long before we became a party to the conflict. Our textile, leather, paper, and paint industries, to mention only a few, were nearly paralyzed by the fact that no dyes came in from abroad. Then we learned that the dye industry is indeed pivotal, essential to other industries employing millions and earning interest on billions of the people's money.

The only way to be free from the danger of monopolies held by other nations is to

have a home source of supply. Quite recently there has been another example of the danger and the necessity for safeguarding the public interest.

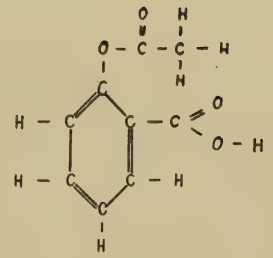
Camphor is a product of very great importance because it is essential to the making of celluloid plastics, an industry whose products are valued at more than $10,000,000 annually. It is obtained from the camphor laurel, and this grows chiefly on the Island of Formosa. Japan, by virtue of her possession of the source of supply, holds a monopoly of camphor; recently she decided to curtail her exports to this country. The price of camphor rose abruptly. The condition would have been disastrous had not the chemists in this country perfected a process for making this essential from the yellow pine instead of the laurel. The advantage is apparent.

If the coal-tar crudes obtained here are made into colors abroad, the millions of dollars representing the cost of producing these from the crudes will go to foreign labor, foreign chemists and foreign company owners. Economically, it is unwise to allow the industry to leave this country.

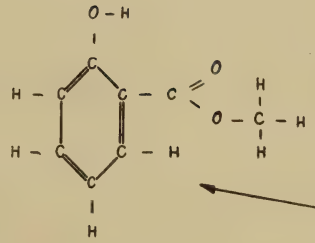
War has come to mean more than a supply of men, guns and munitions; there are special paints which will not show when viewed through light filters used by airmen; there are varnishes (dopes) for the wings of airplanes; and compositions which will disinfect fresh wounds—an infinite complexity of materials.

A great many of these are furnished by that sister of the dye industry employed in making drugs, both therapeutic and prophylactic. This other industry is vital and should exist among us. It cannot develop to the fullest extent except in conjunction with the dye industry.

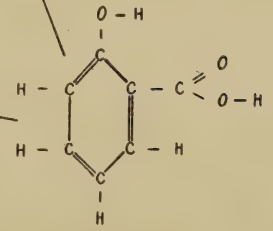
How close the relationship is, the chemist's formulas show; the molecule of acetyl salicylic acid (aspirin) may serve as an example.



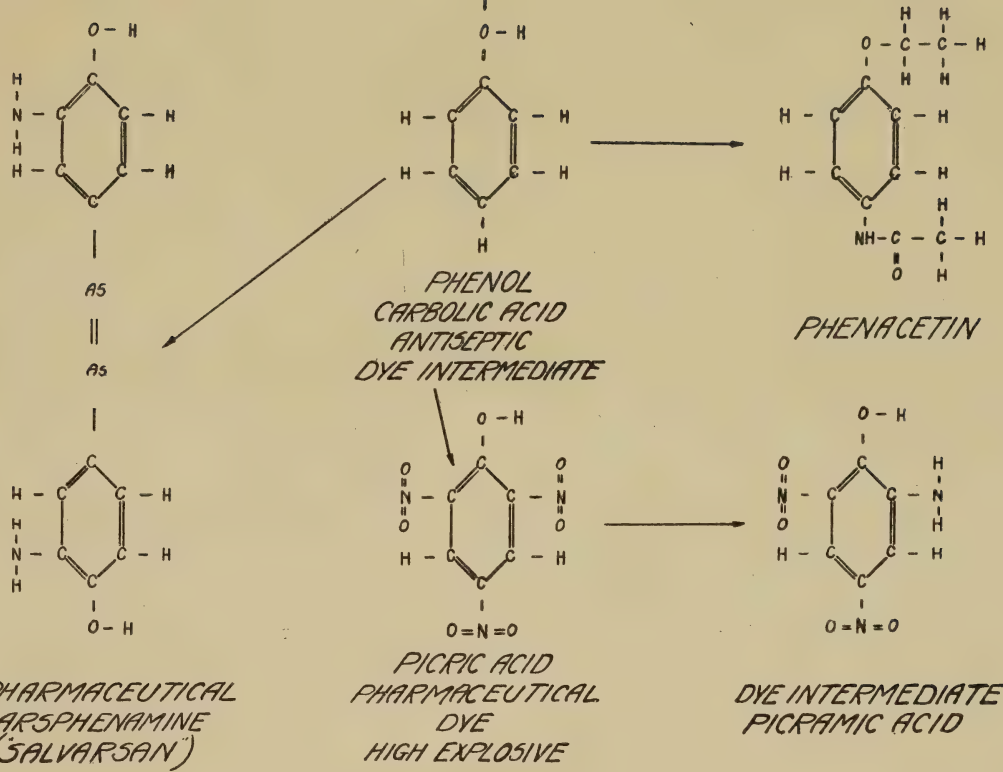
ACETYL SALICYLIC ACID
ASPIRIN



OIL OF WINTERGREEN
METHYL SALICYLATE



SALICYLIC ACID
ANTIRHEUMATIC
ANTISEPTIC
DYE INTERMEDIATE


PHENOL
CARBOLIC ACID
ANTISEPTIC
DYE INTERMEDIATE
PHENACETIN
PHARMACEUTICAL
ARSPHENAMINE
(SALVARSAN)
PICRIC ACID
PHARMACEUTICAL
DYE
HIGH EXPLOSIVE
DYE INTERMEDIATE
PICRAMIC ACID

Atoms do not always arrange themselves as wanted; frequently there are two possibilities and two kinds of molecules are formed. Sometimes the dye-maker is forced to produce substances useful as material for making drugs, but useless in dyes; sometimes the maker of drugs finds that his by-products can be used only as dye intermediates.

Dye intermediates can be fashioned into drugs—aniline into antifebrine, ortho-anisidine into guaiacol. To take one industry from the other is to handicap both, to make both less economical.

There can be no doubt of the value of the pharmaceutical industry; it transcends nationality; it serves humanity. It supplies the materials which in skillful hands make possible the mitigation, alleviation or cure of faults within our own bodies. It furnishes the munitions with which man fights his greatest foe—bacteria—in the war that is ever raging.

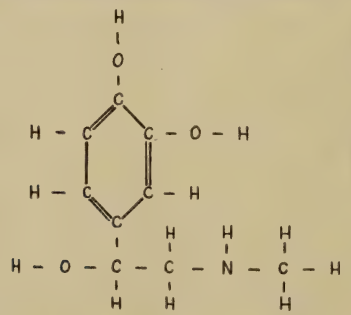
Chemical warfare is no new thing; it is as old as disease. Tear-gas and sneeze-producer are the inventions of the microbes of a cold; the pneumococcus gases its victims; the bacteria of tuberculosis, typhoid, influ-

enza, plague, the diseases of childhood, each attacks with a different poison "gas."

Unfortunately, the "gassing" of victims is so much taken for granted that the nations make no real, concerted effort to overthrow enemies much more terrible, much more malignant, than any met with on the field of battle. Only when a devastation, such as that of the influenza epidemic comes, do the people appear to be alive to the necessity of an effort; a little money is spent, not one-tenth of that devoted to the building of a battleship—then forgetfulness; except in the laboratories and clinics where men and women work as best they can with the little they have to spend.

The organic chemical industry, as a whole, not only fashions remedies; it supplies stains, reagents, disinfectants and the multitude of materials necessary in the study of disease. One hundred years ago medicine was nearly as empirical a "science" as in the days of Aesculapius. To-day the organic chemist designs molecules to fight disease, just as he does dyes to give certain effects. He makes these for the physician's use, veronal, novocain, antifebrine; these are but a few of them.

Cocain is a natural drug; it and others in its class the chemist isolates in a pure form with constant properties, a great improvement on the crude material formerly used. He analyzes these molecules, determines which grouping of atoms is really active, then builds new molecules which will emphasize one or another of the properties of the natural substance. Within the normal body, growth, blood pressure, secretion are automatically controlled and the balance held by substances of many kinds. The active materials have in two cases already been isolated and analyzed and one can now be made from coal-tar in any desired quantity for use in treating the abnormal body. Adrenalin, the active principle which controls the blood pressure, this simple molecule of extraordinary power,



is an article of manufacture.

Such skill is a long way from that needed for the collection of herbs in the light of the full moon—but this is only the beginning.

The ideal remedy for infectious disease would be to kill all the micro-organisms, bacteria or trypanosoma, without hurting the body—the very notion sounds hopeless. It means disinfecting a tremendously complex organism of extreme sensitiveness, made up of innumerable living cells—and yet this apparently hopeless problem, this incredible nicety of chemical action, lies within the grasp of chemical therapeutics. The chemist can fashion molecules which act like spears, the "head" of each being a group of atoms which will only strike into the body's foes, and to the "head" is attached another group of atoms which kills the micro-organisms or renders them so weak that they fall before the natural defenses of the body. The real meaning of this modern miracle is hard to grasp. These poisoned arrows are molecules smaller than those of Pontamine Black EX. They are thrown into the blood stream. They recoil harmlessly from the body cells, but penetrate the invaders when they strike them. Explosives to crush fortresses in the fighting of human warfare; "arrows" smaller

than the least living thing to destroy the body's enemies within our bodies—such are the weapons that organic chemistry fashions! Does this industry not deserve a home here?

What has been done points the way to what shall be done. The things undiscovered transcend in importance those already known. This nation must be strong in war, but even more, it must lead in the betterment of mankind. In both cases the matter is in reality one of man and molecules. It is necessary for this country to control her war molecules; it does not seem so necessary that she should control the making of those used in the efforts of peace.

It is true that to the world it does not matter where the all-important molecules that shall rid the world of infectious disease are discovered; it matters only, and that most profoundly, that the molecules should be discovered. It is our faith that the discoveries will be made more certain, will come sooner if Americans are enrolled in the greatest possible number among those carrying forward the work. But this means

that it does matter to mankind that dye and drug molecules should be made and studied here in factory and laboratory, because this activity is a fundamental prerequisite to the high evolution of that which must be America's contribution to the welfare of the world.

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